Original Article

Evaluation of arterial phase images with 90vp in multiphase abdominal CT scan

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Abstract

Introduction: CT scan of abdomen is usually performed in 120-140 kVp and such high ranges of kilovoltage in all phases will increases the radiation dose many fold. The purpose of the study was to qualitatively and quantitatively assess image quality with low kVp in arterial phase of examination of multiphasic abdominal CT study.

Methods: A prospective cross-sectional study was done in 206 participants of age 18 to 88 years who were undergoing multiphase CT studies of the abdomen in Neusoft 16 detector MDCT. After performing non contrast scan, arterial phase study of limited region of abdomen (diaphragm to infrarenal margins) was obtained with 90 kVp. The portovenous phase scan with standard protocol was obtained (120kVp). All other scanning parameters were kept same for two phases. Images were rated on 5 point scale (1-worst, 2-Suboptimal,3-adequate,4-very good,5-excellent) based on visualization of boundaries, anatomical details of the organs and visualization of noise and artifact by two radiologists. Patient weight, abdominal circumference (AC), height and BMI were recorded and correlated with the image quality score. Statistical analysis was done with Wilcoxon's signed ranks test k test and descriptive analysis.

Results: Overall the image quality of portovenous phase was significantly better ($p<0.005$) than low kVp arterial phase. Image quality score correlated best with abdominal circumference in standard dose technique ($r=0.54$) and patient weight in reduced dose technique ($r=0.44$). Arterial phase scanning had acceptable image quality score for patient weight of <60 kg, AC <80cm and BMI<25 kg/m2. The $CTDI_{vol}$ was 7.71 with reduced kVp protocol and 20.02 with standard resulting significant reduction in radiation dose of about 61%

Conclusions: The image quality of arterial phase images with 90kVp tube potential is acceptable in thin and average built patients. Hence reduction in radiation dose is possible if arterial phase scanning is done with reduced kVp except in patients with large anthropometric parameters.

Keywords: Arterial phase, CT, Image quality, Low kVp, Radiation dose,

Introduction

Computed tomography (CT) also known as computed axial tomography is an invaluable radiological diagnostic imaging modality. Today MDCT technology with advanced computer and CT software are being used. Its application for different indication has grown exponentially over the years, rising from 3 million in 1980 to 67 million in 2006, an equivalent of a 600% increase from 1980 to 2006. CT examination comprises 7 % of all radiological examination contributing more than 40% radiation dose[2,3]. Most of the time when protocol driven CT technique is used and the technical parameters (kVp, mAs, pitch & SL) are constant and not adjusted accordingly to different body habitous of patients. The CT image quality is influenced by scanning parameters. Multiphase and thin slice volume imaging are increasingly being used for better diagnostic efficacy which also increases the radiation dose. It is a known fact that the estimated risk of radiation induced cancer and other effects are also proportional to radiation dose and hence dose reduction is very essential.

Radiation dose to patients can be reduced by optimizing scanning parameters. Scanning the arterial phase in low kVp is one the methods. The use of low kilovoltage of 90 kVp has various additional advantages in post contrast studies like better CNR and better contrast enhancement with effective utilization of k-edge absorption of iodine contrast[2,4]. Till the reluctance to use low kilovoltage technique is due to uncertainty about getting acceptable images, as there is lack of studies using low tube voltage and acceptable image quality. The use of lower tube potential in pediatric patients has been investigated by different investigators and established for routine practice. However there is lack of study involving the adult population with lower tube potential in arterial phase of multiphase study.. Image quality of arterial phase with reduced tube potential could be assessed by categorizing these images into different acceptability score. If diagnostically acceptable images are obtained with reduced dose in arterial phase then a protocol could be established and applied in routine clinical practice.

The image quality depends on different patient biometrics. It is essential to determine the optimal tube potential for different biometric range to produces diagnostically acceptable images. If upper limit of patient's parameters are determined for low voltage technique then the technique could be applied in such groups. Furthermore by establishing the relationship between image quality and patient parameters the exposure factors could be selected accordingly and the best patient biometric could be formed.

Even though there are advantages of using low tube voltage in arterial phase imaging, there is still dilemma to use the low voltage. CT manufacturers generally optimize the CT protocols with radiation doses in higher range for better image quality and clarity. Radiologic technologists should also be aware of amount of radiation dose reduction while using low voltage. The scan parameters used in our institution are according to European body standard. Nepalese population has different body standards like weight and abdominal circumference. So in our context, kilovoltage should be modified according to the body standards.

If a relationship between image quality and patient biometrics is established by using low kVp and routinely practiced there will be a significant breakthrough in radiation dose reduction and diagnostic technique optimization.

Methods

This was a prospective cross-sectional study carried out in the Department of Radiology and Imaging, Tribhuvan University Teaching Hospital, Kathmandu. A total of 206 patients with age > 17 years were included in the study (convenient sampling) from July1st 2013 to October 31st 2013. The exclusion criteria included patient with very large anthropometric measurement and uncooperative patient .The study was approved by the institutional review board of the Institute of Medicine. A written informed consents was taken from each patient. Patients biometric parameters were measured. Computed tomography was performed with Neusoft's NeuViz 16 slice CT scanner.Abdomen was imaged from the level of diaphragm to pubic symphysis. Volumetric data were obtained with standard technical factors for abdominal imaging (kVp-120, mA-288 pitch 0.8631 collimation of 0.625 mm, Gantry rotation 0.75s FOV 300 mm scan circle and matrix size of 512x512). After taking standard noncontrast images, a total of 100 ml of iodinated contrast (Ioversol) containing 320 mgI/ml was intravenously administered as a bolus via an auto injector with injection rate of 3-4ml/s. Arterial phases images of upper abdomen(diaphragm-lower boarder of kidneys) were obtained with reduced tube voltage of 90 kVp. Portovenous phase was obtained with standard parameter with post injection delay of 45-50s covering whole abdomen. The delayed phases images were taken with standard exposure parameter when necessary. Image noise in arterial phase and portovenous phase study in erector spinae muscle (at the level of right renal artery origin) was carefully measured preventing any possible region of fatty infiltration[4]. These images were blindly reviewed in workstation for quality scoring (1-worst,2-suboptimal,3-acceptable,4-verygood,5-excellent) by two radiologists having equal expertise on abdominal CT interpretation who rated the images of each phase. The arterial phases images were reviewed in (WW-500 and WL -40) and portovenous images in (WW-350 and WL-40) were reviewed and then recorded. Statistical analysis was done. (Wilcoxon's signed rank test and Pearson's correlation coefficient). A 95% confidence interval was taken, and p<0.05 were termed as statistically significant.

Results

A total of two hundred and six patients were enrolled in the study among them, 108 (52.4%) were male and 98(47.6%) were female (Fig 1)

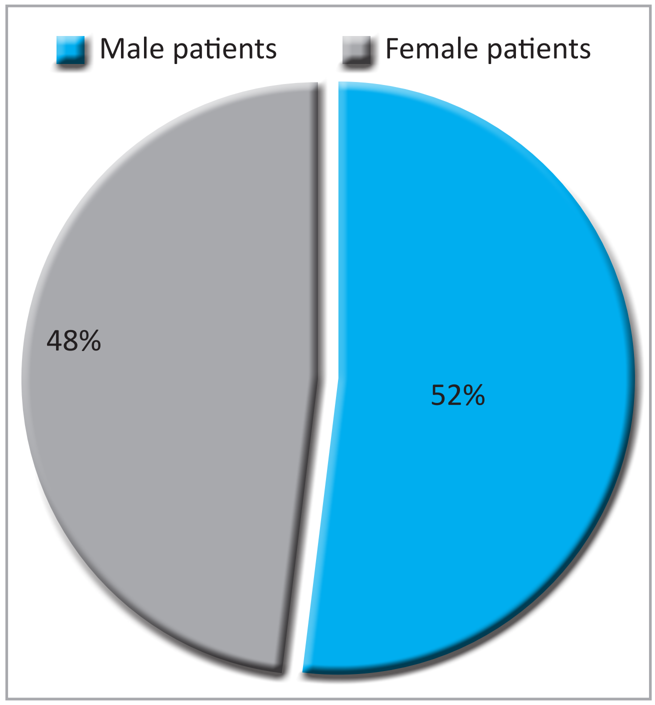


Fig. 1. Gender distribution of subjects

There was wide age distribution of study subjects,5 patients were below 20 years; and 6 persons were above 80 years. The mean age and range of age were 52 years and 18-88 years (Fig.2). The bulk of the study population had age of more than 40 years.

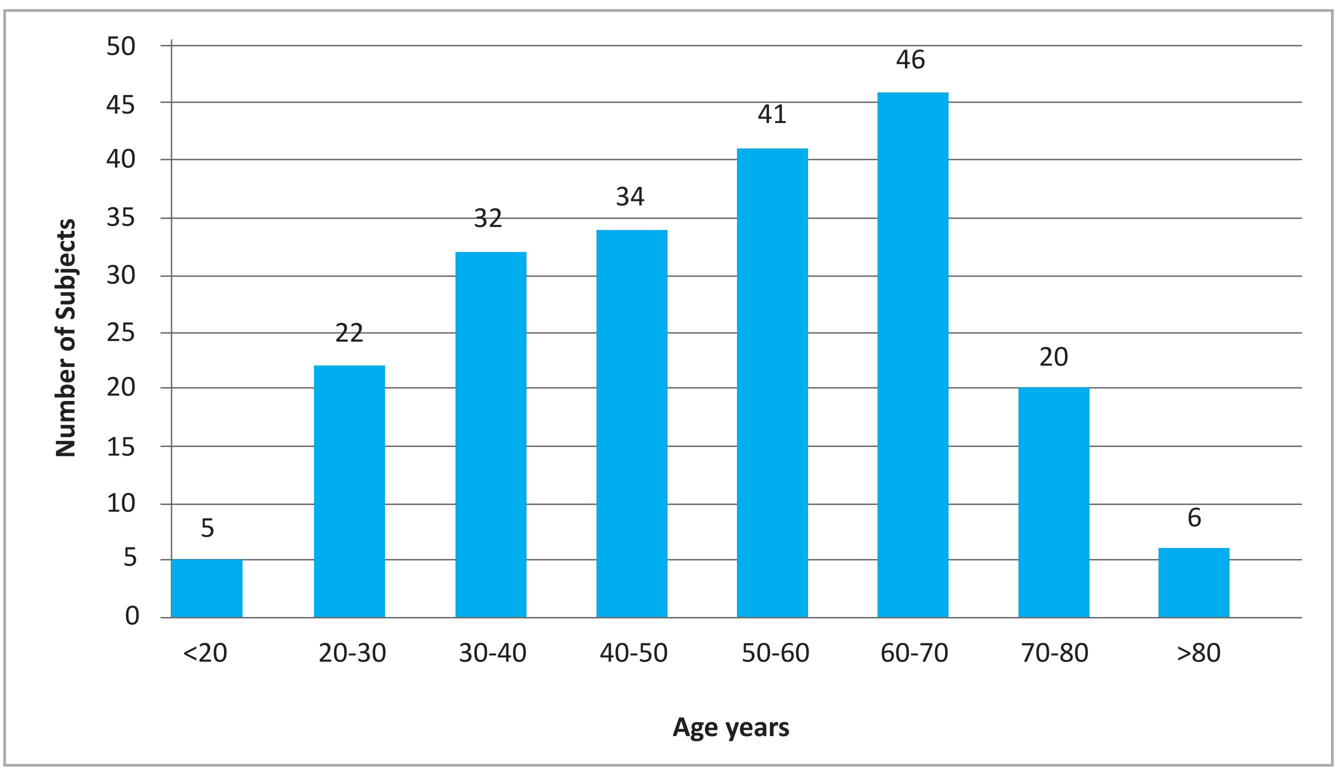


Fig.2. Age distribution of subjects

Inter-observer agreement

Image quality was assessed by different image quality score and Inter observer agreement between two radiologists was calculated by kappa statistics. Kappa value for arterial phase was found to be 0.65 and corresponding value for porto-venous phase was found to be 0.63. Showing good inter-observer agreements. (Table 1).

Table No.1. Inter observer agreement for different protocol

Protocol	Kappa value (k*)
Arterial phase	0.665
Portovenous phase	0.639

*Parenthesis indicates value of kappa calculated from kappa statistics (value of k and strength of agreement <0.2-poor, 0.21 to 0.4 fair, 0.41 to 0.6 moderate, 0.61-0.8-good and 0.8-1- very good).

Relationship between image noise and patient biometrics

Image quality was also assessed by image noise measurement. Image noise was significantly higher in arterial phase with mean noise value of 18.2 was found. Average image noise value in portovenous phase found significantly lower.

Image noise was found to be associated with patient weight and abdominal circumference. As weight of the patient increases there was more image noise in the image. For the patient's weight of 108Kg image noise value in arterial phase is higher than 40.There was less variation in image noise value was found in lower weight range. The image noise was progressing linearly with increment of patient weight.(fig3)

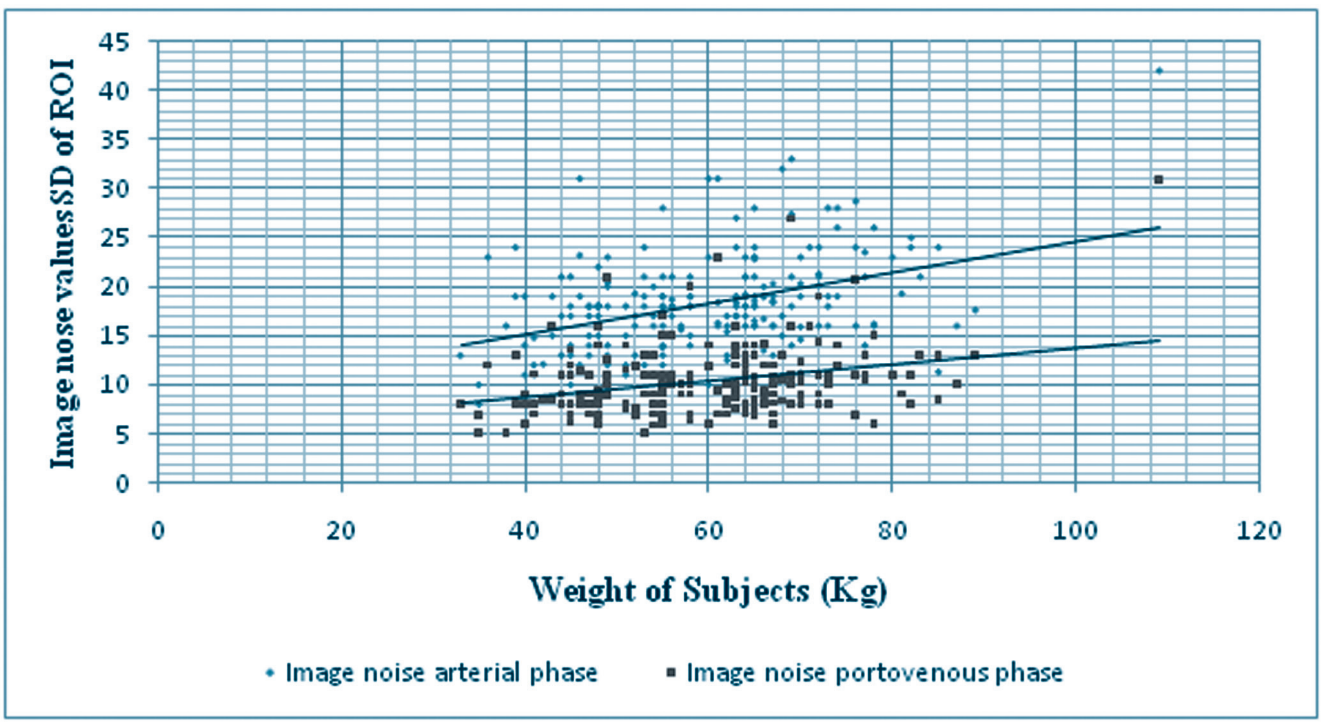
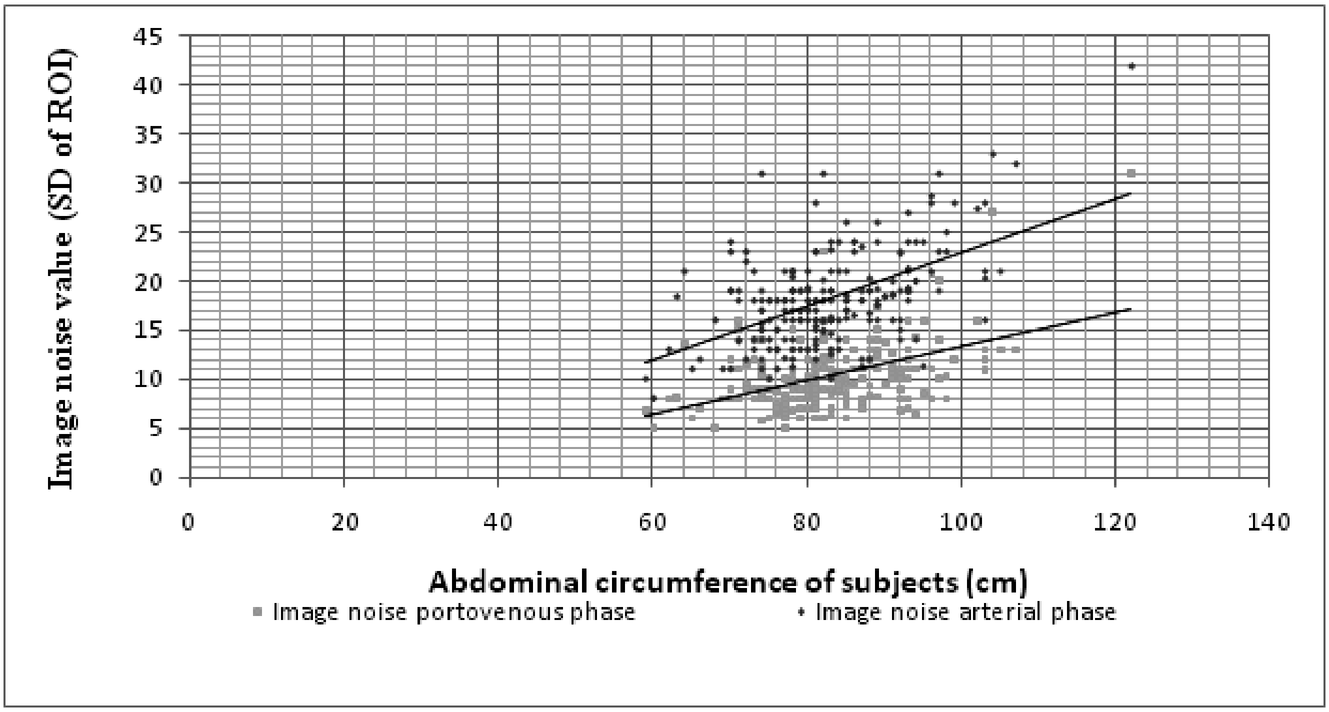


Fig 3. Relationship between image noise and patient's weight

There was a direct relationship between image noise and patient abdominal circumference. Increase in abdominal circumference showed corresponding increase in image noise. Image noise in both phases was less than 10 for abdominal circumference for up to 60 cm. More variation in image noise was found in arterial phase. Image noise was more than 25 for abdominal circumference of more than 100 cm. (fig-4)

Fig. 4. Relationship of image noise and patient's AC.



Average Image quality score of different phase comparison

The image quality score for different phase with different kVp was assessed by Wilcoxon signed ranks test. The score of porto-venous phase was significantly better than arterial phase .The mean image quality score of arterial phase imaging was higher than 3 and for porto-venous phase was higher than four.(Table-2).

Table No. 2. Average results of image quality score by two radiologists for different scanning protocol.

Protocol	Arterial phase	Porto-venous	P value
Radiologist A	3.12	4.12	0.00
Radiologist B	3.02	4.10	0.00

Correlation of image quality with patient's biometrics

The image quality score was found to be associated with different patient parameter. The correlation was calculated by Pearson's correlation coefficient with significant P value. At standard dose, there was highest correlation with patient abdominal circumference followed by patient weight (Table 3). Whilst at reduced dose level, the highest correlation was found with patient weight (Table 4).The least correlation was found with patient height on both protocols.

Table No. 3. Statistical correlation between standard dose image quality score and subject's biometrics

Parameters	Correlation coefficients	P values
Weight	-0.499	0.000
Abdominal circumference	-0.54	0.000
Body mass index	-0.43	0.000
Height	-0.33	0.000

Table no. 4. Statistical correlation between reduced dose image quality score and subject's biometrics in reduced r

Parameters	Correlation coefficients	P values
Weight	-0.44	0.000
Abdominal circumference	-0.40	0.000
Body mass index	-0.38	0.000
Height	-0.30	0.000

Estimation of dose

From the manufacturer data which was provided with the scanner (CTDI vol), we estimated the amount of radiation dose and estimated dose burden to patient using European conversion coefficients (conversion coefficient for abdomen =0.015 used). There was significant dose reduction of about 61% with equivalent scan length.

Discussion

MDCT examination is contributing significant amount of radiation dose to patients with highest dose from CT of abdomen. Though CT constitutes about 7% of all radiological examination, it contributes more than 30% of radiation exposure from medical x-ray sources. Although nonionizing imaging modalities like MRI is being used as an alternative technique of CT scan however for abdominal imaging CT is the most preferred technique till date. Minimizing radiation hazard is of prime importance in CT examination. The use of low kilovoltage imaging in arterial phase is one of the options for reducing radiation dose. A study was conducted using low kilovoltage technique (90kVp) in arterial phase imaging of multiphase abdominal study. The result showed diagnostically acceptable image quality in average and thin built adults thus reducing the risk of radiation hazards. A range of patient biometrics were also established where a low voltage scanning is possible without increasing compensatory mAs. Some studies like Nakaura et. al (2011)[5],used different methods of increasing the exposure (increasing mAs) to compensate for image noise created during low voltage imaging and other studies showed correlation of patient parameter with standard dose Kalra et.al.(2003)[4]. The methodology used in present study was different and hence direct comparison of all results with other studies was not possible.

For the optimization of scanning parameters Kalra et.al. (2003)[4] performed abdominal CT study with 50% dose reduction (240-300mA vs 120-150 mA) by obtaining the extra scan with reduced dose at suprarenal area in portovenous phase. They found good inter observer agreements and concluded that 50% dose reduction is possible for patient parameter with weight less than 81 kg (mean quality score 3.2) and abdominal circumference of less than 105 cm (mean quality score 3.14). But our study found that reduced voltage scanning was acceptable with patient weighing less than 60 kg(mean quality score 3.15) and abdominal circumference of less than90cm (mean quality score3) with good inter-observer agreement for both arterial and portovenous phases (kappa arterial phase 0.66 and kappa for portovenous phase 0.63).

Nakayama et.al. (2006)[2],. had conducted a study of abdominal angiography with 90kVp instead of standard 120 kVp and concluded that angiographic images were diagnostically acceptable in patients weighing up to 70 kg. Our findings showed acceptable image quality using 90 kVp in patients weighing up to 60 kg (Image quality score 3.2).The difference in the image quality with regard to weight is possibly due to tissue/organ imaging in our study and only vascular imaging in their study.

The effect of decreasing tube kiolovoltage has important implication in post contrast studies. As kilovoltage decreases the effective energy of beam is in the range of 33keV which is in the range of K-edge of iodine that results in better CNR in post contrast images.

In the another study by Prasad et al. with 50% reduced dose in chest imaging different weight categories of patients showed adequate image quality in patients weighing 80kg and above. In our study of abdominal imaging, with reduced kVp the image quality was adequate only up to 60 kg. The contradiction could be possibly due to more scatter radiation from abdominal fat during abdominal scan than in chest scan in heavy built patient.

Our study for acceptable image quality acceptability in standard and reduced dose is similar with findings of Marin et al[11]. They performed a study using low kVp and high mAs in late hepatic arterial phase and compared the image quality in the standard dose. Although low kVp produced better CNR in the study but images quality score was significantly less than in standard dose.

Another study with low kilovoltage technique used for scanning of coronaries by Park et al. which showed similar finding as ours. They used100 kVp in combination with higher mAs and found better CNR and SNR thus reducing dose to patients. Although their study with reduced kiolovoltage was done with compensatory increase in mAs, our study found that there was no additional increment in tube mAs for certain range of weight and abdominal circumference of patients. However for heavy built patients we also suggested mAs increment to reduce image noise and beam hardening.

Hans et al[12]. did a study to establish the correlation between patients biometrics and image quality. They reported that abdominal circumference was the best predictor of abdominal fat than both weight and body mass index (weight (kg)/ height (m^2)) and also concluded it as the best parameter to correlate with image quality score. Our study evaluated other additional parameters like patient weight, height and BMI and found that image quality score at standard dose is best correlated with abdominal circumference and least with patient height, which was the similar with the finding of Hans et al[12] at standard dose. In the present study also found that patient's weight correlated best with image quality score when low radiation dose was used for average built patient.

In the present study there was significant negative correlation between patient biometrics (abdominal circumference and weight) and image quality, along with some internal variations as well. Some pathological conditions like severe ascites and huge abdomino-pelvic mass caused significant noise in images. In three average built patients with gross ascites and four patients with huge abdomino-pelvic mass the CT images with low dose had more noise with lower score in image quality which could be due to greater attenuation of beam by fluid and mass. There were few patients in whom image quality scores were high even though their weight and abdominal circumference were more. As the quality assessment was a subjective evaluation of radiologists their adaptation to view images with low kVp may play important role in quality scoring. Images with reduced dose might achieve better score as well. It emphasizes the need for objective assessment of images quality.

Different guidelines have been developed for radiation optimization. Halliburton et al(2011).[15] have recommended 100 kVp in patient weighing less than 90 Kg and BMI less than30 kg/m2 and 120 kVp when weight is more than 90 kg and BMI greater than 30kg/m^2 for cardiac scanning. It can be recommended from our study also to use low kilovoltage for patients weighing less than 70 kg and BMI less than25 kg/m^2 without any increase in tube current. It is also recommended for increment in mAs for patient weighing more than 70 kg and BMI greater than25kg/m^2. Finding of present study are concurrent with finding of park et al.[16] where cardiac scanning was performed with low kilovoltage in patients having BMI less than 25 kg/m2.

We tried to estimate the possible dose reduction during abdominal scan by using low kilovoltage technique for which the displayed dose CTDI vol data used. Nakayama et al.[2] compared the radiation dose using phantoms in 90kVp and 120 kVp and found that the radiation dose reduction in the center of phantom was 56.8%. The present study also compared the displayed CTDIvol for 90kVp and 120 kVp and found that significantly dose reduction of about 61% in low kVp similar that of Nakayama et al[2]. Another similar phantom study by Marine et.al.[11] had calculated dose reduction of 71% by using 80kVp and attained 71% dose reduction which are similar with present study. Based on $CTDI_{vol}$ data we roughly estimated the possible radiation dose value in multiphasic abdominal CT scanning for a 40 cm scanning length. Our study showed that if multiphase studies (plain+ arterial + Portovenous+ delayed) are done with standard parameters the total effective dose will be 55.6 mSv. However with reduced kVp for arterial and delayed phase it would be 38.74mSv which is equivalent to 30% reduction. If we limit the scanning range only up to 20 cm for arterial and delayed phase it will reduce the dose up to 33.17 mSv (40%) reduction.

Conclusions

The present study showed that there is good correlation between patient weight, abdominal circumference, BMI & height with image quality score. The image quality was found to be better with standard dose than reduced dose. The abdominal circumference of patients best correlated with standard dose and patient weight is best correlated with reduced dose. The present study also recommends patient specific exposure protocol and arterial phase with low voltage is adequate for patient up to <70 kg weight, AC<90cm and BMI <25 kg/m2, a low voltage arterial phase scanning can also possible with some compensatory mAs increment for higher ranges. Such techniques could be utilized in portovenous phase and delayed phases for thin patient.

Patient biometric specific kVp modulation is one option for dose reduction. However patient's pathological condition should be taken into consideration.

The dose reduction method by applying low kVp arterial phase scanning is more advantageous whenever possible low kVp scanning technique should replace the standard dose technique in multiphasic abdominal study.

Conflict of interest: None declared

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